The Respiratory System

CHAPTER OBJECTIVES
After studying this chapter, you should be able to:

1. Explain the function of the respiratory system.
2. Name the organs of the system.
3. Define the parts of the internal nose and their functions.
4. Name the three areas of the pharynx and explain their anatomy.
5. Name the cartilages and membranes of the larynx and how they function.
6. Explain how the anatomy of the trachea prevents collapse during breathing and allows for esophageal expansion during swallowing.
7. Explain what is meant by the term bronchial tree.
8. Describe the structure and function of the lungs and pleura.
9. Describe the overall process of gas exchange in the lungs and tissues.
10. Define ventilation, external respiration, and internal respiration.
INTRODUCTION

The trillions of cells of our body need a continuous supply of oxygen to carry out the various and vital processes that are necessary for their survival. Cellular respiration, which converts food into the chemical energy of adenosine triphosphate (ATP), produces large quantities of carbon dioxide gas. An excess accumulation of this gas in tissue fluids produces acidic conditions in the form of carbonic acid that can be poisonous to cells. Thus, this gas must be quickly eliminated.

The two systems of the body that share the responsibility of supplying oxygen and eliminating carbon dioxide gas are the cardiovascular system and the respiratory system. The respiratory system consists of the organs that exchange these gases between the
atmosphere and the blood. Those organs are the nose, pharynx, larynx, trachea, bronchi, and lungs (Figure 17-1). In turn, the blood in the cardiovascular system transports these gases between the lungs and the cells. The overall exchange of gases between the atmosphere, the blood, and the cells is called respiration. This term is to be distinguished from the biochemical meaning of respiration discussed in Chapter 4. The respiratory and cardiovascular systems participate equally in respiration. If either system malfunctions, the body cells will die from oxygen deprivation and accumulation of carbon dioxide gas and death will be inevitable. See Concept Map 17-1: The Respiratory System.

**FIGURE 17-1.** The organs of the respiratory system.

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**THE ANATOMY AND FUNCTIONS OF THE NOSE**

The nose has an external part and an internal part that is inside the skull (Figure 17-2). Externally, the nose is formed by a framework of cartilage and bone covered with skin and lined internally with mucous membrane. The bridge of the nose is formed by the nasal bones that help support the external nose and hold it in a fixed position. On the undersurface of the external nose are two openings called the nostrils or external nares (ex-TER-nal NAIREZ). The hard palate of the mouth forms the floor of the nasal cavity, separating the nasal cavity from the oral cavity.
Anteriorly, the internal nose merges with the external nose. Posteriorly, it connects with the pharynx (FAIR-inks) or throat via two openings called the internal nares. The nasolacrimal ducts from the lacrimal or tear sacs empty into the nose, as well as four paranasal sinuses (air-filled spaces inside bone): sphenoidal, frontal, ethmoidal, and maxillary. The inside of both the internal and external nose is divided into right and left
nasal cavities by a vertical partition known as the nasal septum. This septum is made primarily of cartilage. The top of the septum is formed by the perpendicular plate of the ethmoid bone and the lowermost portion is formed by the vomer bone. (Review Chapter 7.) The anterior portions of the nasal cavities just inside the nostrils are known as the vestibules (VESS-tih-byoolz). These interior structures of the nose have three specialized functions. First, air is warmed, moistened, and filtered as it enters the nose. Second, olfactory (olh-FAK-toh-ree) stimuli are detected for the sense of smell. Third, large hollow resonating chambers are present for creating speech sounds.

As the incoming air enters the nostril, it first passes through the vestibule. Because the vestibule is lined with coarse hairs, it filters out large dust particles. This is the body’s first line of defense to prevent foreign objects from entering the respiratory system. The air then moves into the rest of the cavity. Three shelves are formed by the projections of the superior, middle, and inferior conchae or turbinate bones. These extend out from the lateral wall of the cavity and almost reach the nasal septum. The cavity is subdivided into a series of narrow passageways called the superior meatus (soo-PEER-ih-or mee-AY-tus), middle meatus, and inferior meatus. Mucous membranes line the cavity and those shelves.

Olfactory receptors are located in the membrane that lines the superior meatus; this area is called the olfactory region. Below, the membrane consists of pseudostratified, ciliated, columnar epithelial cells with many goblet cells that produce mucus. Blood capillaries are also found here. As the air whirs around the turbinate bones and meati, or shelf passageways, it is warmed by the capillaries. Mucus secreted by the goblet cells moistens the air and traps particles not filtered by the hairs in the nose. In addition, drainage from the lacrimal ducts and sinuses help moisten the air. The cilia on the free edge of the epithelial cells move this mucus-dust package back toward the throat so it can be swallowed and eliminated from the body through the digestive system. Its enzymes and acidic environment will destroy most microorganisms that may have entered with the air. The cold virus and the flu virus are not destroyed.

FIGURE 17-2. Sagittal view of the nasal cavity and pharynx.
THE STRUCTURE AND FUNCTIONS OF THE PHARYNX

The pharynx is also called the throat. It is a tube approximately 5 inches (13 cm) long that begins at the internal nares and extends part way down the neck. Its position in the body is noted just posterior to the nasal and oral cavities and just anterior to the cervical vertebrae. Its walls are made of skeletal muscle lined with mucous membrane. The pharynx is a passageway for both air and food and forms a resonating chamber for speech sounds. It is divided into three portions (see Figure 17-2).

The uppermost portion is called the nasopharynx (nay-zoh-FAIR-inks). It has four openings in its walls: the two internal nares and, just behind those, the two openings that lead into the auditory or eustachian (you-STAY-shen) tubes. In its posterior wall the pharyngeal or adenoid tonsils are located.

The second portion is called the oropharynx (or-oh-FAIR-inks). It has only one opening, the fauces (FOH-sez), which connects with the mouth. Hence, the oropharynx is a common passageway for both food and air. The palatine and lingual tonsils are found in the oropharynx.

The lowermost portion is called the laryngopharynx (lah-ring-FAIR-inks). It connects with the esophagus posteriorly and with the larynx anteriorly. The pharynx or throat serves as both a connection between the mouth and the digestive tract and as a connection between the nose and the respiratory system.

THE LARYNX OR VOICE BOX

The larynx (LAIR-inks) is also called the voice box (Figure 17-3). It is a very short passageway that connects the pharynx with the trachea. Its walls are supported by nine pieces of cartilage. Three of the pieces are single and three are paired. The three single pieces are the thyroid (THIGH-royd) cartilage, the epiglottis (ep-ih-GLOT-iss), and the cricoid (KRYE-loyd) cartilage.

The thyroid cartilage is the largest piece of cartilage and is also known as the Adam’s apple. It is larger in males than in females and can be easily seen externally, moving up and down when a person is speaking or swallowing. The epiglottis is a large, leaf-shaped piece of cartilage. It lies on the tip of the larynx. It can be viewed in its entirety from a posterior view, but, anteriorly, one can only see its tip. The stem part is attached to the thyroid cartilage, but the leaf part is unattached and is free to move up and down like a trap door. When we swallow, this free edge or leaflike part pulls down and forms a lid over the glottis (GLOT-iss). The glottis is the space between the vocal cords in the larynx. The larynx is closed off when we swallow, so that foods and liquids get routed posteriorly into the esophagus and are kept out of the trachea anteriorly. If anything other than air passes into the larynx, a cough reflex should dislodge the foreign material.

When we try to talk and swallow at the same time, we choke and the cough reflex functions. Sensory receptors in the larynx detect the foreign substance and send a signal to the medulla oblongata, which triggers the cough reflex. Air is taken in and the vestibular folds and vocal cords tightly close trapping the air in the lungs. Muscular contractions increase the pressure in the lungs and the cords open,
forcing air from the lungs at a very high velocity and carrying any foreign substance with it.

The cricoid cartilage is a ring of cartilage that forms the lowermost or inferior walls of the larynx. It attaches to the first ring of cartilage of the trachea. This is the last of the three unpaired cartilages. The six paired cartilages consist of three cartilages on either side of the posterior part of the larynx. The paired **arytenoid** cartilages are ladle-shaped and attach to the vocal cords and laryngeal muscles and by their action they move the vocal cords. The **corniculate** cartilages are cone-shaped; the paired **cuneiform** cartilages are rod-shaped. The cuneiforms are located in the mucous membrane fold that connects the epiglottis to the arytenoid cartilages.

The mucous membrane of the larynx is arranged into two pairs of folds: an upper pair called the **vestibular** folds or false vocal cords; and a lower pair called the vocal folds or true vocal cords (Figure 17-4). When the vestibular folds come together, they prevent air from exiting the lungs as when you hold your breath. Along with the epiglottis, the vestibular folds can prevent food or liquids from getting into the larynx. Under the mucous membrane of the true vocal cords lie bands of elastic ligament, stretched between pieces of rigid cartilage like the strings of a guitar. Skeletal muscles of the larynx are attached internally to the pieces of rigid cartilage and to the vocal folds. When the muscles contract, the glottis or opening is narrowed.

As air exits the lungs and is directed against the vocal cords, they vibrate and set up sound waves in the column of air in the pharynx, nose, and mouth. The greater the pressure of air, the louder the sound. Take a full breath of air in and force it out all at once. You will create a very loud sound.

**FIGURE 17-4.** The position of the vocal cords in the larynx.
However, if you take in a full breath of air and let it out slowly with less pressure, the sound you create will be much softer sounding. Pitch is controlled by tension on the true vocal cords. When the cords are pulled taut by the muscles, they vibrate more rapidly and a higher pitch results. Decreasing the muscular tension produces lower pitch sounds. Try it. Because the true vocal cords are usually thicker and longer in men than in women, they vibrate more slowly so men have a lower range of pitch than women.

Sound originates from the vibrations of the true vocal cords. In humans, this sound is converted into speech. The pharynx, mouth, nasal cavities, and the paranasal sinuses all function as resonating chambers. The movement of the tongue and cheeks also contributes to creating the individual quality of human speech.

THE TRACHEA OR WINDPIPE

The trachea (TRAY-kee-ah) is also referred to as the windpipe (Figure 17-5). It is a tubular passageway for air approximately 4.5 inches in length and about 1 inch in diameter. It is found anterior to the esophagus and extends from the cricoid cartilage of the larynx to the fifth thoracic vertebra, where it divides into the right and left primary bronchi.

The tracheal epithelium is pseudostratified, ciliated columnar cells with goblet cells and basal cells. The goblet cells produce mucus, and the ciliated cells provide the same protection against dust particles as does the membrane in the larynx and pharynx. The cilia beat upward and move the mucus-dust package to the throat for elimination from the body. The smooth muscle and elastic connective tissue of the trachea are encircled by a series of 16 to 20 horizontal incomplete rings of hyaline cartilage that resemble a stack of Cs. The open part of the Cs face the esophagus and allow it to expand into the trachea during swallowing. When we swallow, we stop breathing to permit the large food bolus to expand into the trachea on its way to the stomach. The solid part of the Cs provides a strong rigid support for the tracheal walls so that they do not collapse inward and obstruct the air passageway. Varying pressure, as air moves in and out of the trachea, would collapse the tube if the cartilaginous rings were not present.

If a foreign object becomes caught in the trachea and cannot be expelled by the cough reflex, a tracheostomy

FIGURE 17-5. The trachea, bronchi, and bronchioles. (A) Anatomy of the trachea and bronchial tree. (B) End of the bronchial tree showing the terminal bronchioles, alveolar duct, and alveoli.
may be necessary to save the person’s life. A tracheostomy is an incision into the trachea creating a new opening for air to enter. It is usually done between the second and third tracheal cartilages. This temporary opening can be closed, once the blocking object has been removed.

THE BRONCHI AND THE BRONCHIAL TREE

The trachea terminates in the chest by dividing into a right primary bronchus (RITE PRYE-mary BRONG-kus) that goes to the right lung and a left primary bronchus that goes to the left lung (see Figure 17-5 [A]). The right primary bronchus is more vertical, shorter, and wider than the left. Consequently, if a foreign object gets past the throat into the trachea, it will frequently get caught and lodge in the right primary bronchus. The bronchi, like the trachea, also contain the incomplete rings of hyaline cartilage and are lined with the same pseudostratified, ciliated columnar epithelium.

On entering the lungs, the primary bronchi divide to form smaller bronchi called the secondary or lobar bronchi, one for each lobe of the lung. The right lung has three lobes and the left lung has two lobes (Figure 17-6). The secondary bronchi continue to branch forming even smaller bronchi called tertiary or segmental bronchi. These branch into the segments of each lobe of the lung. Tertiary or segmental bronchi divide into smaller branches called bronchioles (BRONG-kee-olz). Bronchioles finally branch into even smaller tubes called terminal (end) bronchioles (see Figure 17-5 [B]). This continuous branching of the trachea resembles a tree trunk with branches. For this reason this branching is commonly referred to as a bronchial tree (see Figure 17-5 [A]).

As the branching becomes more and more extensive, the rings of cartilage get replaced with plates of cartilage. These finally disappear completely in the bronchioles. As the cartilage decreases, the amount of smooth muscle in the branches increases. In addition the pseudostratified, ciliated columnar epithelium changes to a simple, cuboidal epithelium.

**StudyWARE™ Connection**

Play an interactive game labeling structures of the bronchi and lobes of the lungs on your StudyWARE™ CD-ROM.
Individuals who smoke or are constantly exposed to secondhand smoke create a constant irritation to the trachea. Over time, this irritation from smoke can cause the epithelium of the trachea to change from a pseudostratified, ciliated columnar epithelium to a stratified, squamous epithelium. Without cilia, the epithelium cannot clear the passageway of mucus and debris. This provides an environment ideal for the growth of microorganisms, leading to respiratory infections. This constant irritation and respiratory inflammation triggers the cough reflex, resulting in what we call a smoker’s cough.

THE ANATOMY AND FUNCTION OF THE LUNGS

The lungs are paired, cone-shaped organs located in and filling the pleural divisions of the thoracic cavity. Two layers of serous membrane, known as the pleural (PLOO-rah) membrane, enclose and protect each lung (Figure 17-7). The outer layer attaches the lung to the wall of the thoracic cavity and is called the parietal (pah-RYE-eh-tal) pleura. The inner layer is called the visceral (VISS-er-al) pleura and covers the lungs. Between these two layers is a small space called the pleural cavity, which contains a lubricating fluid that is secreted by the membranes. This pleural fluid prevents friction between the two membranes and allows them to slide past each other during breathing, as the lungs and thorax change shape. It also assists in holding the pleural membranes together. Pleurisy (PLOOR-ih-see), or pleuritis, is an inflammation of this area and is very painful. The right lung with its three lobes is thicker and broader than the left lung with its two lobes. The right lung is also a bit shorter than the left because the diaphragm muscle is higher on the right side, as it must

make room for the liver that is found below it. The left lung is thinner, longer, and narrower than the right.

The segment of lung tissue that each tertiary or segmental bronchi supplies is called a bronchopulmonary (bronk-oh-PULL-mon-air-ree) segment. Each of these segments is divided into many small compartments called lobules (LOB-yoolz) (see Figure 17-7). Every lobule is wrapped in elastic connective tissue and contains a lymphatic vessel, an arteriole, a venule, and bronchioles from a terminal bronchiole.

Terminal bronchioles subdivide into microscopic branches called respiratory bronchioles. These respiratory bronchioles further subdivide into 2 to 11 alveolar (al-VEE-oh-lar) ducts or atria. Around the circumference of the alveolar ducts are numerous alveoli (al-VEE-oh-lye) and alveolar sacs. An alveolus (singular) is a cup-shaped or grapelike out-pouching lined with epithelium and supported by a thin, elastic basement membrane. Alveolar sacs are two or more alveoli that share a common opening. Refer to Figure 17-8 for the anatomy of an alveolus.

**FIGURE 17-8.** The anatomy of an alveolus.
The actual exchange of the respiratory gases between the lungs and blood occurs by diffusion across the alveoli and the walls of the capillary network that surrounds the alveoli. This membrane, through which the respiratory gases move, is referred to as the alveolar-capillary or respiratory membrane. The surface of the respiratory membrane inside each alveolus is coated with a fluid, consisting of a mixture of lipoproteins called surfactant (sir-FAK-tant). This material is secreted by certain alveolar cells (alveolar type II cells). Surfactant helps reduce surface tension (the force of attraction between water molecules) of the fluid. Therefore, surfactant helps prevent the alveoli from collapsing or sticking shut as air moves in and out during breathing. The gases need only diffuse through a single squamous epithelial cell of an alveolus and the single endothelial cell of the capillary to reach the red blood cell inside the capillary. It has been estimated that the lungs contain over 300 million alveoli. This is an immense surface area of 70 square meters (753 square feet) for the exchange of oxygen and carbon dioxide. This is about the square footage of a small house or cottage.

THE RESPIRATION PROCESS

The principal purpose of respiration is to supply the trillions of cells of the body with oxygen and to remove the carbon dioxide gas produced by cellular activities. There are three basic processes of respiration. The first process is ventilation or breathing, which is the movement of air between the atmosphere and the lungs. Ventilation has two phases: inhalation or inspiration to move air into the lungs and exhalation or expiration to move air out of the lungs (Figure 17-9).

The second and third processes of respiration involve the exchange of the gases within the body. External respiration is the exchange of gases between the lungs and the blood, the second process. The third process is called internal respiration, which is the exchange of gases between the blood and the body cells.

When the diaphragm and external intercostal muscles contract, we breathe in. This occurs because as the dome-shaped diaphragm contracts, it moves downward and flattens and the height of the thoracic cavity increases. During inhalation the diaphragm presses the abdominal organs forward and downward. During exhalation the diaphragm rises and recoils to the resting position.
Simultaneous contraction of the external intercostals lifts the rib cage and pushes the sternum forward. The lungs get stretched to the larger size of the thorax. Gases within the lungs spread out to fill the larger space, resulting in a decrease in gas pressure, causing a vacuum that sucks air into the lungs. This is inspiration.

As the diaphragm and external intercostals relax, the rib cage descends, the space decreases, and the gases inside the lungs come closer together. Pressure increases, causing the gases to flow out of the lungs. This is expiration and we breathe out. This is mainly a passive activity. When we force air out, the internal intercostal muscles contract to help further decrease the size of the rib cage.

**COMMON DISEASE, DISORDER, OR CONDITION**

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<th>BRONCHITIS</th>
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<td><strong>Bronchitis</strong> (brong-KIGH-tis) is an inflammation of the bronchi. The inflamed tissue causes a swelling of the mucous membrane. This produces increased mucous production with a decrease in the ability of the cilia to move the mucus up to the throat. This results in a decrease in the diameter of the bronchial tubes, impairing breathing. Bronchitis can be caused by an infection with bacteria or viruses. It can also develop from increased exposure to irritants like air pollutants or cigarette smoke.</td>
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<th>EMPHYSEMA</th>
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<td><strong>Emphysema</strong> (em-fi-SEE-mah) is characterized by the destruction of the walls of the alveoli. It is a progressively degenerative disease with no cure. It develops from prolonged exposure to respiratory irritants like tobacco smoke and air pollutants. As alveolar walls are destroyed, the surface area of the respiratory membrane is decreased. This decreases the amount of gas that can be exchanged. The alveolar walls also lose some elasticity, which decreases the ability of the lungs to recoil and expel air. Symptoms include enlargement of the thoracic cavity and shortness of breath. The progress of the disease can be slowed by removing the source of irritants, such as stopping smoking, or the use of bronchodilators to assist in breathing.</td>
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<th>LUNG CANCER</th>
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<td><strong>Lung cancer</strong> is the most common cause of cancer deaths in the United States. Cancers that begin in the lungs are called primary pulmonary cancers. The most common form originates from uncontrolled growth of epithelial cells and is known as bronchogenic carcinoma. This form develops in response to prolonged exposure to irritants like tobacco, smoke, CO(_2), dust, asbestos, radiation, and vinyl chloride. Because of the rich blood supply in the lungs, cancer in the lung can readily spread to other parts of the body. Lung cancer is treated with surgery, radiation, and chemotherapy but is difficult to curtail. Survival rates for patients with lung cancer remain low. Symptoms include a persistent cough, difficulty breathing, excessive sputum, or blood containing sputum.</td>
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<th>CYSTIC FIBROSIS</th>
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<td><strong>Cystic fibrosis</strong> (SIS-tik fye-BROH-sis) is an inherited disease. It affects the secretory cells of the lungs. Due to abnormal chloride ion secretions, the mucus becomes very thick or viscous. It tends to accumulate in the lungs because it does not get moved by cilia. This results in difficulty in breathing due to obstructions by the mucus of the airways and severe coughing, which attempts to remove the mucus. The disease was once fatal in childhood, but today individuals with the disease can live into early adulthood. New research in genetic engineering may one day cure this disease.</td>
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<th>PNEUMOCONIOSIS</th>
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<td><strong>Pneumoconiosis</strong> is caused by excessive exposure to asbestos, silica, or coal dust (black lung disease). It is the replacement of lung tissue with fibrous connective tissue. The lungs are not elastic and breathing becomes very difficult.</td>
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RESPIRATORY DISTRESS SYNDROME

Respiratory distress syndrome, or hyaline membrane disease, is common in premature infants. This is caused by too little surfactant being produced and the lungs tend to collapse (surfactant is not produced in adequate amounts until after 7 months of development). Without special treatment, most premature babies will die shortly after birth as a result of inadequate ventilation and tiring of respiratory muscles.

PNEUMONIA

Pneumonia (new-MOH-nee-ah), or pneumonitis, refers to any infection in the lungs. Most pneumonias are caused by bacterial infections. However, some are viral, fungal, or protozoan in origin. Individuals with AIDS commonly are infected with a protozoan, Pneumocystis carinii, which causes pneumocystis pneumonia. Symptoms of pneumonia include fever, chest pain, fluid in the lungs, and difficulty in breathing.

WHOOPING COUGH

Whooping cough, or pertussis, is caused by an infection with the bacterium Bordetella pertussis. It results in a loss of the cilia of the epithelium that lines the respiratory tract. Mucus accumulates and severe coughing attempts to expel the material. A childhood vaccine is now available to prevent this disease.

LARYNGITIS

Laryngitis (lar-in-JIGH-tis) is an inflammation of the mucosal membrane lining of the larynx. Symptoms include a swelling of the vocal cords with either a complete loss of voice or a very hoarse and rasping voice. This condition can develop as an accompanying symptom of a cold, by excessive use of the voice (as the condition occasionally develops in professional singers and orators), or by bacterial or viral infections of the respiratory tract. It can also be caused by excessive exposure to smoke or irritating fumes. The acute condition can be accompanied by a painful and scratchy feeling in the throat along with a cough. A common treatment is to inhale aromatic vaporized steam with menthol, pine oil, or tincture of benzoin. Children under five years of age who develop this condition can progress to serious respiratory distress. Chronic laryngitis is treated by using an astringent antiseptic throat spray, avoiding smoking and secondhand smoke, avoiding other irritants, resting the vocal cords periodically, and occasionally using a vaporizer.

PLEURISY

Pleurisy (PLOOR-ih-see) is an inflammation of the parietal pleura of the lungs. Symptoms include difficulty in breathing and a stabbing pain when the lungs are inflated. Simple pleurisy, also called dry or fibrinous pleurisy, does not produce excessive fluid in the pleural cavity between the parietal (outer layer) pleura and the visceral (inner layer) pleura, whereas pleural effusion pleurisy produces considerable amounts of fluid in the pleural cavity with extensive inflammation. Causes of pleurisy include pneumonia, tuberculosis, abscesses of the lung or chest wall, and bronchial tumors. Treatment consists of pain relievers and therapy for the disease that caused the condition.

ATELECTASIS

Atelectasis (at-ee-LEK-tah-sis) is a condition of a collapsed lung or reduction in the volume of a part of a lung. This results from an accumulation of either air or fluid in the pleural cavity. It can also result from a loss of pressure in the lung or reduced elastic recoil of a lung.
Legionnaire’s disease, also known as legionellosis, is caused by exposure to the gram-negative bacterium Legionella pneumophila, which produces an acute pneumonia. Symptoms include a flu-like illness followed by chills, high fever, headache, and muscle aches within a week. The disease may progress to pleurisy, a dry cough, and occasionally diarrhea. Contaminated whirlpool spas, air-conditioning towers, and stagnant warm water can be sources of the bacteria. The disease got its name from the first episode of the disease that occurred in a hotel during an American Legion convention in 1976. Treatment includes the use of antibiotics like tetracycline and erythromycin.

Sudden infant death syndrome (SIDS)

Sudden infant death syndrome or SIDS is also known as crib death. It is the unexpected death of a healthy infant that happens during sleep when the child stops breathing. It is the most frequent cause of death in infants between two weeks and one year old. It occurs in one out of every 300 to 350 births. The cause remains unknown and controversial. Abnormal development of the respiratory centers in the brain may be a factor. Other proposed causes are prolonged apnea, a defect in the respiratory mucosa, and immunoglobulin deficiencies. There are no preventative treatments. As a preventative measure, infants should be placed for sleep on their backs or on their sides. Children at risk are those between 10 and 14 weeks of age, premature babies, infants with respiratory infections, those whose mothers are less than 20 years of age, and mothers who smoke or use drugs. It occurs more often in female babies than in males.

COMMON COLD

The common cold is a contagious infection of the upper respiratory tract caused by a form of the rhinovirus. Its symptoms include nasal dripping, sneezing, excessive tearing, and malaise. It may be accompanied by a low-grade fever and may affect the lower respiratory tract resulting in occasional coughing. The common cold usually lasts about a week. It is treated by rest, increased fluid intake, and decongestants.

INFLUEZENA (FLU)

Influenza (in-flew-EN-zah) or flu is a highly contagious viral infection of the respiratory tract. It is caused by a myxovirus. Three main strains have been identified: Type A, B, and C. New strains of the virus continually evolve hence why yearly vaccinations with the current prevalent virus is recommended, especially for the very young, the elderly, and debilitated persons at risk. The strains are usually named for either the area (Asian flu) or the organism from which the strain evolved (bird flu). Symptoms include fever and chills, sore throat, cough, headache, muscle aches, and fatigue. The virus is transmitted in airborne droplets.

TUBERCULOSIS (TB)

Tuberculosis (too-ber-kew-LOH-sis) or TB is a chronic bacterial infection that usually affects the lungs. It is caused by the bacillus bacterium Mycobacterium tuberculosis. It can be transmitted by the ingestion or inhalation of infected droplets. The bacterium can also infect other organs of the body such as the spleen, liver, lymph nodes, bone marrow, as well as the meninges of the central nervous system. Early symptoms of pulmonary tuberculosis include chest pain, fever, loss of appetite with accompanying weight loss, and pleurisy. The tissue of the lungs react to the presence of the bacterium by producing cells that phagocytize the organism forming tubercles, hence, the name tuberculosis. If untreated the tubercles can enlarge and merge forming clumps of dead tissue filling the lung cavity. This results in the patient coughing up blood.
The pressure of a gas will determine the rate at which it diffuses from one area to another. Review the discussion of diffusion in Chapter 2. Molecules move from an area of high concentration to an area of low concentration. In a mixture of gases, like the air, each gas contributes a portion of the total pressure of the mixture. The partial pressure of a gas is the amount of pressure that gas contributes to the total pressure and is directly proportional to the concentration of that gas in the mixture. Air is 78% nitrogen, 21% oxygen, and 0.04% carbon dioxide, and the rest a mixture of other gases. Because air is 21% oxygen, it makes up 21% of atmospheric pressure (21% of 760 mm Hg). We can abbreviate the partial pressure of oxygen as \( P_{O_2} = 160 \text{ mm Hg} \) and carbon dioxide as \( P_{CO_2} = 0.3 \text{ mm Hg} \) in air.

When a mixture of gases dissolves in blood, the resulting concentration of each gas is proportional to its partial pressure. Each gas diffuses between the blood and its surrounding tissues from areas of high partial pressure to areas of low partial pressure, until the partial pressure in the areas reaches equilibrium. The \( P_{CO_2} \) in capillary blood is 45 mm Hg. The \( P_{CO_2} \) in alveolar air is 40 mm Hg. Because of these differences in partial pressures, carbon dioxide diffuses from blood, where its partial pressure is higher at 45 mm Hg, across the respiratory membrane into alveolar air, where its partial pressure is lower at 40 mm Hg. Similarly, the \( P_{O_2} \) of capillary blood is 40 mm Hg, while that of alveolar air is 104 mm Hg. Therefore, oxygen diffuses from alveolar air, where the partial pressure is higher at 104 mm Hg, into the blood, where the partial pressure is lower at 40 mm Hg. The blood then leaves the lungs with a \( P_{O_2} \) of 104 mm Hg (Figure 17-10).

**HEALTH ALERT**

**CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)**

Chronic obstructive pulmonary disease is a progressive disorder characterized by long-term obstruction of airflow, which results in diminished inspiration and expiration capabilities of the lungs. The disease includes emphysema, asthma, and chronic bronchitis. In most cases, COPD is preventable since smoking and breathing in secondhand smoke are its most common cause. Other causes of COPD include exposure to dusts and gases at the workplace, chronic air pollution, and pulmonary infections. Pulmonary infections can be treated with antibiotics to slow down the progress of the disease. However, no cure exists if emphysema has set in. Patients with COPD experience difficulty with breathing during physical exertion. They cannot inhale or exhale deeply and usually have a chronic cough. The disease is also referred to as chronic obstructive lung disease.

**HEALTH ALERT**

**ASTHMA**

Asthma is characterized by recurring spasms of difficulty with breathing. An individual with asthma has symptoms such as wheezing while exhaling and inhaling, shortness of breath, and coughing. These are caused by a narrowing of the bronchial passageway and a buildup of a viscous mucoid secretion in the bronchial tubes. The exact causes of asthma are unknown although allergies are commonly associated with asthma attacks. Inhalation of pollen, dust mites, and animal dander as well as vigorous exercise, emotional stress, and inhalation of very cold air can trigger an asthma attack. Approximately 3–6% of the population experiences asthma. Symptoms may reverse spontaneously or with therapy. Children who experience asthma can become symptom-free after the onset of adolescence (this occurs in about 25–50% of cases). Treatment may include elimination of the causative agent, hyposensitization, use of an aerosol bronchodilator, or short-term use of corticosteroids.
The blood then transports oxygen to tissue cells and picks up carbon dioxide waste from the tissue cells. The tissue cells are high in carbon dioxide from cellular metabolic activities and low in oxygen, because it is used up in those activities. The pressure of CO₂ is higher in tissue cells than in blood cells and diffuses from tissues to blood cells. The blood cell is higher in O₂ levels than the tissue cells; thus, the pressure of O₂ in blood is higher and diffuses into tissue cells, where it is lower. Recall that it is the iron atoms in heme that carry the oxygen and the protein globin that carries the carbon dioxide. The hemoglobin molecule in the red blood cell transports these gases.

**FIGURE 17-10.** The respiratory pathway of oxygen and carbon dioxide.

**StudyWARE™ Connection**

Watch an animation about respiration on your StudyWARE™ CD-ROM.

**LUNG CAPACITY**

Lung capacity is the lung volume that is the sum of two or more of the four primary, nonoverlapping lung volumes. There are four lung capacities. The first is...
functional residual capacity (FRC) and is the volume of gas in the lungs at the end of a normal tidal volume exhalation. The FRC is equal to the residual volume plus the expiratory reserve volume. The second is inspiratory capacity (IC) and is the maximum volume of gas that can be inhaled from the end of a resting exhalation. It is measured with a spirometer and is equal to the sum of the tidal volume and the inspiratory reserve volume. The third capacity is total lung capacity (TLC). It is the volume of gas in the lungs at the end of a maximum inspiration. It equals the vital capacity and the residual capacity. The fourth capacity is the vital capacity (VC). It is the maximum volume of air that can be expelled at the normal rate of exhalation after a maximum inspiration. This represents the greatest possible breathing or lung capacity. It equals the inspiratory reserve volume plus the tidal volume plus the expiratory reserve volume.

As we advance in age, the respiratory muscles weaken and the chest wall becomes more rigid due to a stiffening of the costal cartilages and ribs. The tissues of the respiratory tract become less elastic and more rigid. This includes the alveolar sacs, resulting in a decrease in the lung capacity. This decrease can amount to almost 35% when individuals reach their 70s.

The levels of oxygen gas being carried by the blood also decrease as we age, and gas exchange across the respiratory membranes of the alveoli decreases. In spite of these changes, older adults are capable of light exercise regimens and are encouraged to do so in order to maintain their muscle tone, strength, and endurance. The ciliary action of the epithelium lining the respiratory tract decreases with age, resulting in a buildup of mucus inside the respiratory passageways. This is why older adults become much more susceptible to bronchitis, pneumonia, emphysema, and other respiratory infections.

**Integumentary System**
- The skin is the first line of defense because it forms a barrier to protect respiratory organs and tissues from microorganisms.
- Stimulation of receptors in the skin can alter respiratory rates.

**Skeletal System**
- Bones provide attachments for the muscles involved in breathing, for example, the intercostals.
- The ribs and sternum enclose and protect the lungs and bronchi in the thoracic cavity.

**Muscular System**
- The diaphragm and intercostal muscles produce changes in the volume of the thorax and lungs, resulting in the ability to inhale and exhale.
- The respiratory system eliminates the carbon dioxide produced by contracting muscle cells.

**Nervous System**
- The brainstem has control centers that regulate the respiratory rate.
- The respiratory system supplies nerve cells with needed oxygen for maximum efficiency.

**StudyWARE™ Connection**
Watch animations on asthma on your StudyWARE™ CD-ROM.
Endocrine System
● Hormones stimulate red blood cell production, and the blood cells carry the oxygen and carbon dioxide for the respiratory system.
● Epinephrine dilates bronchioles, increasing breathing abilities.
● Testosterone causes the enlargement of the thyroid cartilage, producing the prominent Adam’s apple in men.

Cardiovascular System
● The heart pumps the oxygen carrying red blood cells from the lungs through its system of arteries and veins to tissue cells where oxygen is exchanged with carbon dioxide.

Lymphatic System
● The immune system protects respiratory organs from infection and cancers.
● The tonsils in the pharynx produce immune cells.

Digestive System
● The pharynx is used by both the digestive and the respiratory systems.
● The digestive system provides nutrients to respiratory organs and tissues.

Urinary System
● The kidneys and the respiratory system help maintain blood pH.

● The kidneys reabsorb the water lost through breathing by filtering water from the blood.

Reproductive System
● Breathing rates increase during sexual activities.
● Fetal respiration occurs through the placenta with the mother.

SUMMARY OUTLINE

INTRODUCTION
1. The organs of the respiratory system are the nose, pharynx, larynx, trachea, bronchi, and lungs.
2. Respiration is the overall exchange of the gases oxygen and carbon dioxide between the atmosphere, the blood and the cells.
3. The cardiovascular and respiratory systems equally share the responsibility of supplying oxygen to and eliminating carbon dioxide gas from cells.

THE ANATOMY AND FUNCTIONS OF THE NOSE
1. The openings into the external nose are called the nostrils or external nares.
2. The internal nose connects with the throat or pharynx via the two internal nares.
CHAPTER 17  The Respiratory System

3. The nose is separated into a right and left nasal cavity by the nasal septum.

4. Coarse hairs line the vestibules of the nostrils to filter out large dust particles in the air.

5. The internal nose has three shelves formed by the turbinate bones: the superior, middle, and inferior meatus lined with mucous membranes.

6. The olfactory receptors are found in the superior meatus.

7. The internal nose has three functions: air is warmed, moistened, and filtered; olfactory stimuli are detected; and large hollow resonating chambers are provided for speech sounds.

THE STRUCTURE AND FUNCTIONS OF THE PHARYNX

1. The pharynx or throat has two functions. It is a passageway for both food and air, and it forms a resonating chamber for speech sounds.

2. The pharynx is divided into the nasopharynx, the oropharynx, and the laryngopharynx.

3. The nasopharynx has four openings in its walls: the two internal nares and the openings to the two eustachian tubes. It also houses the pharyngeal tonsils.

4. The oropharynx has one opening, the fauces or connection to the mouth. It houses the palatine and lingual tonsils.

5. The laryngopharynx connects with the esophagus posteriorly and the larynx anteriorly.

THE LARYNX OR VOICE BOX

1. The walls of the larynx are supported by nine pieces of cartilage; three are single and three are paired.

2. The thyroid cartilage is the largest single piece. It is also called the Adam's apple and is usually larger in men.

3. The epiglottis is a large, single leaf-shaped piece of cartilage. It pulls down over the glottis when we swallow to keep food or liquids from getting into the trachea.

4. The cricoid cartilage is a single ring of cartilage that connects with the first tracheal ring.

5. The paired arytenoid cartilages are ladle-shaped and are attached to the vocal cords and laryngeal muscles.

6. The paired corniculate cartilages are cone-shaped, and the paired cuneiforms are rod-shaped.

7. The mucous membrane of the larynx is arranged in two pairs of folds. The upper pair is the vestibular folds or false vocal cords, and the lower pair is the vocal folds or true vocal cords.

8. The glottis is the opening over the true vocal cords.

9. Air coming from the lungs causes the vocal cords to vibrate and produce sound. The greater the volume of air, the louder the sound.

10. Pitch is controlled by tension on the true vocal cords. The stronger the tension, the higher the pitch. True vocal cords are thicker in men; they vibrate more slowly and produce a lower pitch than that in women.

THE TRACHEA OR WINDPIPE

1. The trachea is a 4.5-inch tubular passageway for air and is located anterior to the esophagus.

2. Its epithelium is pseudostratified, ciliated columnar cells with goblet cells that produce mucus, and basal cells.

3. Its smooth muscle and connective tissue are encircled by incomplete rings of hyaline cartilage shaped like a stack of Cs.

4. The open part of the Cs faces the esophagus and allows it to expand into the trachea during swallowing.

5. The closed part of the Cs forms a solid support to prevent collapse of the tracheal wall.

6. If a foreign object gets caught in the trachea, a cough reflex expels it.

THE BRONCHI AND THE BRONCHIAL TREE

1. The right primary bronchus branches from the trachea and goes to the right lung; the left primary bronchus branches and goes to the left lung.

2. The primary bronchi branch into secondary or lobar bronchi that go into the lobes of the lungs. The right lung has three lobes and the left lung has two.

3. The secondary bronchi branch into tertiary or segmental bronchi, which branch into the segments of the lobes of the lungs.

4. Tertiary or segmental bronchi branch into smaller branches called bronchioles.

5. Bronchioles finally branch into the smallest branches called terminal bronchioles.

6. Because this continuous branching of the bronchi resembles a tree and its branches, it is referred to as a bronchial tree.
THE ANATOMY AND FUNCTION OF THE LUNGS

1. The pleural membrane encloses and protects each lung. It is composed of two layers of serous membranes: the outer is the parietal pleura and the inner is the visceral pleura.

2. Between these two layers is the pleural cavity, which contains a lubricating fluid to prevent friction as the lungs expand and contract during breathing.

3. The segment of lung tissue that each tertiary or segmental bronchi supplies is called a bronchopulmonary segment.

4. Each of these segments is divided into a number of lobules wrapped in elastic connective tissue with a lymphatic, an arteriole, a venule, and bronchioles from a terminal bronchicle.

5. Terminal bronchioles subdivide into microscopic respiratory bronchioles, which further divide into 2 to 11 alveolar ducts or atria.

6. Around the circumference of the alveolar ducts are alveoli and alveolar sacs.

7. Alveoli are grapelike outpouchings of epithelium and elastic basement membrane surrounded externally by a capillary network.

8. An alveolar sac is two or more alveoli that share a common opening.

9. The microscopic membrane through which the respiratory gases move is this alveolar-capillary (respiratory) membrane.

THE RESPIRATION PROCESS

1. There are three basic processes of respiration.

2. The first process is called ventilation or breathing, which is the movement of air between the atmosphere and the lungs.

3. The two phases of ventilation are inhalation or inspiration, which moves air into the lungs, and exhalation or expiration, which moves air out of the lungs.

4. The second process of respiration is external respiration, which is the exchange of gases between the lungs and the blood.

5. The third process is internal respiration, which is the exchange of gases between the blood and body cells.

6. Breathing in occurs when the diaphragm and external intercostal muscle contract, causing decreased pressure and a vacuum in the lungs.

7. When the diaphragm and external intercostal muscles relax, we breathe out due to increased pressure in the lungs forcing the air out. This is mainly a passive activity.

8. The partial pressure of a gas is the amount of pressure that gas contributes to the total pressure and is directly proportional to the concentration of that gas in the mixture.

9. The partial pressure of oxygen is \( P_{O_2} = 160 \) mm Hg and of carbon dioxide \( P_{CO_2} = 0.3 \) mm Hg in air.

10. Each gas diffuses between blood and its surrounding tissues from an area of high partial pressure to an area of low partial pressure until equilibrium is reached.

11. The \( P_{CO_2} \) in capillary blood is 45 mm Hg, but it is 40 mm Hg in the alveolar blood of the lungs. Therefore, carbon dioxide diffuses from blood into the lungs.

12. The \( P_{O_2} \) in capillary blood is 40 mm Hg, but it is 104 mm Hg in the alveolar sacs of the lungs. Therefore, oxygen diffuses from the lungs into the blood cells.

13. As the blood cells transport their high levels of oxygen to tissue cells, the tissue cells are low in oxygen but high in carbon dioxide; therefore, carbon dioxide diffuses into the blood cell and oxygen diffuses from the blood cell into the tissue cell.

LUNG CAPACITY

1. Lung capacity is the lung volume that is the sum of two or more of the four primary, nonoverlapping lung volumes.

2. There are four lung capacities: functional residual capacity (FRC); inspiratory capacity (IC); total lung capacity (TLC); and vital capacity (VC).

REVIEW QUESTIONS

1. Name the three functions performed by the internal structures of the nose.

2. Name the three parts of the pharynx and their functions.

3. Name and describe the three processes in respiration.

4. Name the cartilages that support the trachea.
**5.** Explain how breathing depends on muscular contraction, relaxation, and changes in lung pressure.

**6.** Explain how the anatomy of the tracheal walls accommodates both breathing and swallowing.

**7.** What does the partial pressure of a gas mean?

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**Critical Thinking Questions**

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**MATCHING**

Place the most appropriate number in the blank provided.

- Eustachian tubes
- Fauces
- Vestibular folds
- Alveoli
- Trachea
- Epiglottis
- Adam's apple
- Tertiary bronchi
- Secondary bronchi
- Ventilation

- Surface for respiration
- Thyroid cartilage
- Segmental bronchi
- Blocks glottis during swallowing
- Auditory/nasopharynx
- Breathing
- Lobar bronchi
- Windpipe
- Opening from mouth
- True vocal cords
- False vocal cords
- Cricoid cartilage

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**Search and Explore**

- Choose one of the Health Alerts in this chapter. Perform an Internet search to learn more about the condition. Imagine that you have just been diagnosed with this condition. Write about how your life would be affected and how you feel about that. As a health care provider, do you think it is important to consider the whole individual rather than treating just the disease? Explain your answer in your notebook.

- Visit the American Cancer Society website at http://www.cancer.org to learn more about lung cancer. Based on your research and in your own words, write a description of lung cancer based on your research and list some possible causes. Discuss two ways lung cancer can be prevented.

- Choose one of the structures of the respiratory system. In your own words, briefly describe the structure and explain its importance to this system.

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**StudyWARE™ Connection**

- Choose one of the Health Alerts or Disorders in this chapter. Perform an Internet search to learn more about the condition. Imagine that you have just been diagnosed with this condition. Write about how your life would be affected and how you feel about that. As a health care provider, do you think it is important to consider the whole individual rather than treating just the disease? Explain your answer in your notebook.

- Visit the American Cancer Society website at http://www.cancer.org to learn more about lung cancer. Based on your research and in your own words, write a description of lung cancer based on your research and list some possible causes. Discuss two ways lung cancer can be prevented.

- Choose one of the structures of the respiratory system. In your own words, briefly describe the structure and explain its importance to this system.
CASE STUDY

Cadence, a 6-year-old girl, is admitted into the emergency room with shortness of breath, wheezing when exhaling and inhaling, and coughing. Cadence’s mother states that she has had recurring attacks of difficulty with breathing since she was around 8 months old. Just prior to the attack, Cadence had been helping the little boy who lives next door build a snowman.

Questions

1. What type of attack do you think Cadence might be experiencing?
2. What are some of the factors that trigger these attacks?
3. What caused the respiratory symptoms associated with Cadence’s attack?
4. How is this respiratory problem generally treated?
5. What is the likely long-term outcome for children with this condition?

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Study Guide Practice

Go to your Study Guide for more practice questions, labeling and coloring exercises, and crossword puzzles to help you learn the content in this chapter.

LABORATORY EXERCISE: THE RESPIRATORY SYSTEM

Materials needed: A dissecting kit, a fetal pig, and a dissecting pan.

1. Take your fetal pig out of its storage area. You have already made the cut in the neck region when you did your lab exercise on the endocrine system. We will begin in this area. Find the larynx or voice box that you exposed in a previous lab and now note its connection to the trachea. Refer to your fetal pig dissection Figure 16-16 in Chapter 16. Take your scissors and make a cut from the top of the sternum down to the diaphragm muscle; cut number 4 in Figure 17-11. This will open the thoracic cavity and expose the heart and the lungs. Carefully remove the heart with your scissors and forceps; be careful not to cut into the trachea. You want to expose the trachea beneath the heart.
2. Once the heart and its corresponding blood vessels are removed, follow the trachea down until it branches into the right and left primary bronchi. Clear tissue away from the trachea, being careful not to cut into any lung tissue until you see the bronchial branches that go into the lungs. Review all of the parts of the respiratory system that you can see in the thoracic cavity. We observed the nasopharynx, oropharynx, and epiglottis when we did the dissection on the digestive system. Observe these structures one more time.

FIGURE 17-11. Male fetal pig with dissecting guides for incisions. Cut number 4 will expose the thoracic cavity.